Developing and validating a conceptual survey to assess students' understanding of mechanical and electromagnetic waves spectra.

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Abstract. In this paper, we discuss the development and validation of an open questionnaire focused on mechanical and electromagnetic waves spectra. After reviewing existing instruments, we developed a pilot version of the questionnaire and submitted it to 108 high school students. Data collected during the pilot trial suggested us to modify the wording of some questions and to add items that specifically could target spectra plots. Main implications are briefly discussed.

1 Introduction and aims

Since late seventies, a number of concept inventories have been developed in physics education research to assess students' conceptual learning in several areas of physics [1]. However, few have been devoted to assessing students' understanding of mechanical and electromagnetic waves spectra [2]. A first reason to develop such instrument is to refine existing instruments to include also the spectra of sounds and light emitted by different sources [3]. Second, the impact of students' difficulties about graphical representation of waves on their understanding about spectra is still to be investigated [4]. Finally, to better inspect students' understanding of spectra may help scholars and teachers in developing research-based materials to help students bridge classical physics and quantum mechanics. The purpose of the article is to describe our efforts in developing a conceptual test about spectra. The research question that guided the study was: *does the designed questionnaire adequately describe student's knowledge about spectra of mechanical and electromagnetic waves?*

2 Methods

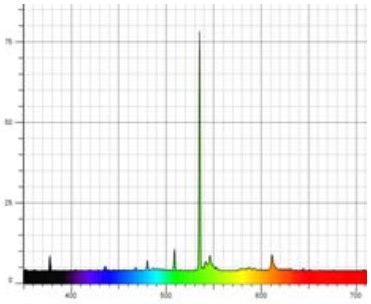
2.1 Instrument design

We first developed a pilot version of the questionnaire featuring ten open general questions about the nature of waves, the mechanism underlying wave emission from a source, and the physical quantities that describe sound and light. The pilot version was then enriched adding five questions about spectra of sound and light. After the pilot trial, the wording and context of some questions were changed. An example of item about light spectra before and after the pilot trial is reported in Figure 1. The final questionnaire featured 15 items.

2.2 Data analysis

We adopted a three-level categorization to assess students' answers: correct, partial and incorrect. For the pilot trial, two raters scored the students' answers with a final inter-rater reliability of about 0.85. Collected answers were then used to improve scoring rubrics.

(a)



(b)

Fig. 1 Questionnaire item about light spectra before (a) and after (b) the pilot trial. (a). The question was: *what kind of source has produced the represented spectrum?* (b) The question was: *what kind of source has produced the represented spectrum? What physical quantities are represented on the axes?*

2.3 Sample and instructional contexts

We submitted the ten-item pilot version as pre-test to 108 high school students attending a 12-hour extra-curricular course at our department. The students had already studied mechanical and electromagnetic waves within curriculum hours. During the activities the students were familiarized with: (i) mechanical waves, measuring the frequency emitted by tuning forks of different length and; (ii) electromagnetic waves, measuring the spectrum emitted by different kind of lamps. The complete 15-item questionnaire was submitted to the same sample as post-test.

3 Results

Table 1 reports the average percentage for the categories of the pilot pre-test (10 questions) and post-test (15 questions). Analysis of the pre-test answers shows that the majority of students (~60%) held incorrect or partial views about waves after traditional instruction. Analysis of the post-test answers suggest also issues with the wording of the questions about spectra.

Table 1. Results of the pilot trial of the questionnaire

	Categories			
Average frequency	Not Given	Incorrect	Partial	Correct
Pre-test	18%	26%	34%	22%
Post-test	28%	21%	27%	23%

4 Conclusion and implications

Analysis of the pilot trial shows that the developed questionnaire can be a useful tool to identify students' difficulties with mechanical and electromagnetic waves. However, issues with the wording of some of the questions emerged. We have improved the pilot version and plan to submit it to a new sample. We will show results of the new implementation at the symposium.

References

[1] Hestenes, D., Wells, M. & Swackhamer, G. Force Concept Inventory. The Physics Teacher, **30**, (1992) 141-151.

[2] Bardar, E. M. *Development and validation of the Light and Spectroscopy Concept Inventory*, *Astronomy Education Review*, **2**, (2007) 103-113.

[3] Barniol P., Zavala G. *Mechanical waves conceptual survey: Its modification and conversion to a standard multiple-choice test, Physical Review Physics Education Research*, **12**, (2016) 010107

[4] Wittmann, M., Steinberg, R. N., & Redish, E. F. Understanding and affecting student reasoning about sound waves. International Journal of Science Education, **25**, (2003) 991- 1013